Can space-time be quantized?

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Space-time cannot be quantized, since it does not exist in the quantum world. In the quantum world, there are only elementary particles with their properties, and spaces of any dimension (1, 2, 3, etc.) do not exist. It can be argued that in the quantum world there is a space-time with dimension 0. That is, it does not exist. Surprisingly, this can be rigorously proven. Moreover, this follows from the fundamental foundations of quantum mechanics and the theory of relativity. Let us examine this issue in more detail.

For further reasoning, I will give a quote [1]:

"...That property of the material world, which in modern language is called dimension, or the number of dimensions of space, was discovered (probably, it's right to say, seen) in ancient times.

The concept of geometric space began to form as far back as Plato in the 4th century BC [3. Gaidenko P. P. Substantiation of scientific knowledge in Plato's philosophy. Moscow: Nauka, 1979. P. 127 - 137].

The definition of geometric objects of different dimensions (point, line, surface, body) and connections between such objects ascends to Plato and the Pythagoreans: **a line is a trace of a moving point**, a surface is a trace of a moving line...

Indeed, **the movement of a point forms a line (that is, a one-dimensional figure)**, the movement of a line forms a surface - a set of "traces" of all points of a moving line (that is, a two-dimensional figure), but the movement of a body can only lead to the formation of another body. Thus, it would seem, three-dimensionality is already distinguished for purely mathematical reasons...".

Now let's remember **that taking into account the theory of relativity, elementary particles must be considered as point objects**. Understanding the point nature of elementary particles is the basis for further reasoning, therefore, we will give an appropriate justification for this statement [2]:

"...In classical mechanics, you can introduce the concept of an absolutely rigid body, that is, a body that cannot be deformed under any conditions. In the theory of relativity, absolutely rigid bodies should accordingly mean bodies, all sizes of which remain unchanged in the frame of reference where they rest. It is easy, however, to see that the theory of relativity makes absolutely impossible the existence of absolutely rigid bodies.

Consider, for example, a circular disc revolving around its axis, and assume that it is absolutely solid. The frame of reference associated with this disk is, of course, not inertial. It is possible, however, to introduce for each of the small elements of the disk an inertial frame of reference in which this element would be at rest at

a given moment; for different elements of the disk with different speeds, these systems will, of course, also be different. Consider a series of length elements located along some radius of the disc. Due to the absolute hardness of the disk, the lengths of each of these segments in the corresponding inertial reference frame remain the same as they are for a stationary disk. The same lengths will be received by the stationary observer measuring them, past which the considered radius of the disk is passing by at the given moment, since each of the segments is perpendicular to its velocity, and in this case there is no Lorentz contraction. Therefore, the entire radius measured by a stationary observer as the sum of its constituent segments will be the same as it is for a stationary disk.

On the other hand, the length of each of the elements of the disk circumference passing by the stationary observer at a given moment undergoes Lorentz contraction, so that the length of the entire circle (measured by the stationary observer as the sum of the lengths of its individual segments) will be less than the circumference of the disk at rest. Thus, we arrive at the result that when the disk rotates, the ratio of its circumference to the radius (measured by a stationary observer) should change instead of remaining equal to 2π. The contradiction of this result with the assumption made shows that in reality the disc cannot be absolutely rigid and during rotation it inevitably undergoes some complex deformation, depending on the elastic properties of the material from which the disc is made.

The impossibility of the existence of absolutely rigid bodies can be convinced in another way. Let some solid body be set in motion by an external action at some point of it. If the body were absolutely solid, then all its points would have to move simultaneously with the one that was affected; otherwise, the body would be deformed. The theory of relativity, however, makes this impossible, since the impact from a given point to the rest is transmitted at a finite speed, and therefore all points of the body cannot simultaneously begin to move.

From what has been said, certain conclusions follow regarding the consideration of elementary particles, that is, particles for which we believe that their mechanical state is fully described by specifying three coordinates and three components of the speed of movement as a whole. Obviously, if an elementary particle had finite dimensions, that is, would be extended, then it could not deform, since the concept of deformation is associated with the possibility of independent movement of individual parts of the body. But, as we have just seen, the theory of relativity shows the impossibility of the existence of absolutely rigid bodies.

Thus, in classical (non-quantum) relativistic mechanics, particles that we consider as elementary cannot be ascribed to finite sizes. In other words, within the limits of the classical theory, elementary particles should be considered as point...”.

Now, remember that in quantum mechanics, particles do not have a trajectory by definition [3]:

"...**In quantum mechanics, there is no concept of particle trajectory. This circumstance constitutes the content of the so-called uncertainty principle** - one of the basic principles of quantum mechanics, discovered by Heisenberg…".

As shown above, **the movement of the point forms a line. The line is a one-dimensional space**. Therefore, **for the particles to have a trajectory, a necessary condition is the presence of space** in which these particles will move. Moreover, the space must be at least one-dimensional.

Consequently, **the absence of the trajectory of elementary particles, which are material points, means that at the quantum level there is not even a one-dimensional space**, but only elementary particles and their properties exist (de Broglie oscillations, particle-wave dualism).

We have already come to this conclusion when we analyzed Zeno's aporias [4]:

"...Zeno of Eleisky in the aporia "Flying Arrow" absolutely strictly showed that if there is a quantization of time, then motion is impossible in principle...

"The flying arrow is motionless, since at every moment of time it occupies an equal position to itself, that is, it is at rest; since it is at rest at every moment of time, then it is at rest at all moments of time, that is, there is no moment in time at which the arrow moves"...

Similarly, in the aporia "Achilles and the Turtle" it is shown that if there is a quantization of space, then no bodies could overcome the distance between themselves. That is, they would not be able to collide, which means there would be no interaction between them...

"The swift-footed Achilles will never catch up with the leisurely turtle, if at the beginning of the movement the turtle is in front of Achilles.

Let's say Achilles runs ten times faster than a turtle and is a thousand steps behind it. During the time it takes Achilles to run this distance, the turtle will crawl a hundred steps in the same direction. When Achilles has run a hundred steps, the turtle will crawl ten more steps, and so on. The process will continue indefinitely, Achilles will never catch up with the turtle".

...**When quantizing space-time, we get elementary particles that are structureless in their essence and exhibit wave-particle properties. It is the wave-particle properties of elementary particles that are the space-time continuum at the quantum level.** There is nothing more! This is the limit!

...Thus, our space-time continuum is formed according to A. Einstein's STR from the Compton wavelength of a microparticle. At distances smaller than Compton's, it makes no sense to talk about lengths, time,

dimensions, etc., since we have a boiling vacuum. Also, an elementary particle has no dimensions, its radius literally tends to zero $r \to 0$.

...At distances greater than the Compton wavelength of an elementary particle, our space-time continuum is already forming. Moreover, an increase in the Compton length "gives rise" to the length itself, that is, the space itself (x, y, z). And the increase in the oscillation time "gives birth" to our time (t).

From the foregoing, it is obvious that time is only just the duration of the oscillation, which we fix in different frames of reference. Therefore, time is a scalar. The time gradient that is formed in space is a simple scalar field that we can observe with our own eyes at a macroscale using the example of the recession of galaxies. Hubble-Lemaitre's law is a direct embodiment of this time gradient...

It is also quite obvious that the space-time continuum is simply an experimental fixation of the spatial and temporal characteristics of oscillations, from a certain frame of reference (according to A. Einstein's STR). Consequently, **the space-time continuum does not consist of the material environment. In fact, it does not exist, it is just a kind of mathematical averaging of the process of oscillation of elementary particles...**".

I would like to emphasize that the absence of the trajectory of elementary particles strictly leads us to the absence of even one-dimensional space at the quantum level. Since in the presence of space and a material point (elementary particle), there would be a trajectory of a particle. But, there is no trajectory in the quantum world, and this is the essence of quantum mechanics, which is expressed by the Heisenberg uncertainty principle.

Consequently, in the quantum world there is no space, even one-dimensional, which means there is no space-time continuum of any dimension. That is, in the quantum world, and in the Universe as a whole, there are only elementary particles that, by their oscillations and properties, form our Universe, including the 4-dimensional space-time continuum.

1. Gorelik G. E. Why is space three-dimensional? Moscow: Nauka, 1982. P. 7.
2. Landau L. D., Lifshits E. M. Theoretical physics. Volume 2. Theory of the field. Moscow: Nauka, 1988. P. 67 - 69.
3. Landau L. D., Lifshits E. M. Theoretical physics. Volume 3. Quantum mechanics. Moscow: Nauka, 1989. P. 14 .
4. Bezverkhniy V. D. Quantization of space-time and Zeno's aporia. ResearchGate (April 2021). P. 1–3. http://dx.doi.org/10.13140/RG.2.2.34726.04163